Water Quality Impacts of the Citarum River on Jakarta and Surrounding Bandung Basin

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Table of Contents

Abstract

The Citarum River within the Bandung Basin of the island of Java, India, is world renowned for its horrendous pollution. A number of pollutants exceed the limits of the official water quality regulation standards of Indonesia. Chemical analysis shows a high BOD (biochemical oxygen demand) and COD (chemical oxygen demand) along with high concentrations of heavy metals. Agricultural and domestic waste also play major roles in pollution of the river. Flooding is common within the region and current trends show a consistent degradation in water quality. Uncertainty regarding the management and testing of water ways also plays a large roll.

Acknowledgements

First and foremost I want to thank Professor Frank Schwartz for his advising and patience throughout this process. I would like to thank The Ohio State University and The School of Earth Sciences for giving me the opportunities that they have over the past 4 years. I also would like to thank Anne E. Carey for helping advise the writing of my thesis as well as providing helpful feedback and information.

Finally, I want to extend my gratitude to my friends, peers, and especially my parents, who pushed me and supported me every step of the way.

Introduction

The Citarum River originating within the Bandung Basin on the island of Java, Indonesia, is notorious for its poor water quality and pollution, and is consistently ranked among the most polluted rivers in the world. The river flows north out of the southern volcanic highlands for a stretch of 270 km and is of strategic importance not only for those living within the watershed, but for the capital city of Jakarta for which it is a main source of water (Sembiring, 2005). Three large multipurpose reservoirs can be found along the river. Large projects have been financed by the Asian Development Bank in order to solve the problems of the Citarum, which include multiple aspects of integrated water resources management: institutional problems, surface- and groundwater management, erosion and sedimentation, flooding and water pollution (van Ginkel, 2015).

Rapid and uncontrolled urbanization, as well as low elevation and an absence of adequate drainage systems has had a negative impact on people's health and environment while also increasing the frequency and intensity of flooding. Waterborne diarrheal disease is a major concern of public health problem impacted by flooding. In 2002, more than 35,000 people in Jakarta ended up suffering from diarrhea disease due to the worst flood in recent history. Enteric viruses are the major cause of the non-bacterial waterborne diseases which are transmitted mainly by the fecal-oral route via contaminated food or water (Phanuwan et al., 2006). One of the most serious problems in Jakarta is the lack of sewerage systems in urban areas; less than 3% of Jakarta's population is connected to a sewer system. Because little sewage is treated in the Jakarta metropolitan area, domestic wastewater including human waste penetrates underground or flows directly into rivers (Kido et al., 2009). The objective of this study is to address the problems of Jakarta and The Citarum River, and the impacts on the people and environment.

Physical Setting

Location of the Study Area

The focus of my study is the Citarum River, which is located adjacent to Jakarta and a number of larger surrounding cities (Figure 1). The Citarum River basin has an area of approximately 6,080 km^2. It rises in the high elevation volcanic terrain in the vicinity of Bandung and flows northward toward the Java Sea. The basin varies in elevation from 660 to 2750 meters above sea level. The watershed is situated approximately 50 km east of Jakarta and was actually a prehistoric intramontane lake an estimated 50,000 years ago. Nowadays the lake bottom forms a large floodplain consisting of lake sediments (van Ginkel, 2015). Diversion canals move water to the city, where it is treated and distributed as part of Jakarta's water supply. In addition, approximately 13 natural and artificial rivers flow through Jakarta, of which the most important are the Ciliwung, Sunter, Pesanggrahan, and Grogol with their tributaries forming the main drainage system for the city (Onodera et al., 2009). Though these rivers are smaller, they are also heavily contaminated, having water qualities on par with the Citarum.

The city is underlain by several aquifers that provide a source of groundwater. This water is generally of a better quality than the surface water and is an important resource for the city. However, excessive pumping along with unlithified sediments within the aquifers has created a serious problem of land subsidence. Besides subsidence, over pumping has lead to brackish water intrusion. Urbanization and subsidence have increased flood risks. Widespread flooding is common (e.g., 1996, 2002 and 2007), inundating up to 40% of the city (Sagala and Pingping, 2015).

Figure 1: Regional map of Java showing the Citarum River Basin in addition to the large cities within the vicinity (Cade Miller, 2016).

Climate

Indonesia is a tropical country located near the equator, which is wet, hot, and humid throughout the year. Temperatures and especially rainfall can vary across the archipelago. Average temperatures near the ocean can range from 28°C to 31°C. Moving to inland plains, the temperature hovers around 26°C, although in mountain regions it is 23°C. The average annual rainfall for Indonesia is around 3,175 millimeters, with the island of Java being among the wettest regions (ADB, 2016). Rainfall is typically higher at higher elevations in the mountains peaks. Weather systems cool as the rise above mountains and can receive up to 6000 millimeters of rain annually. Areas closer to Australia however, can receive as little as 1000 millimeters per year. The study herein focused on Java, specifically an area in and around the city of Jakarta. This area has a high rainfall rate of approximately 3500-4000 millimeters per year. These broad differences in rainfall across Indonesia can be attributed to prevailing wind patterns interacting with local topographic conditions (Hays, 2008).

The climate of Indonesia generally consists of a wet monsoon season and a hot dry season. The wet season ranges from September to March. The dry season occurs in the remaining months of April through August. Most of the rain comes in January and the least rainfaill in July. Timing of the wet and dry seasons can vary from place to place because region in western Indonesia, eastern Indonesia, and Borneo are being influenced by different monsoon wind patterns. A general rule of thumb is that farther south away from the equator, the monsoon season begins and ends later. In this case, the island of Java has its monsoon season from October to April. Drying occurs as high pressure over the Australian deserts moves wind towards the northwest. As the winds near the equator, the Earth's rotation deflect them to the northeast toward the Asian mainland. During the wet monsoon season this process is reversed as now the high pressure system is over the Asia mainland and moves winds in the opposite direction. The resultant monsoon is augmented by humid breezes from the Indian Ocean and produces significant amounts of rain throughout the archipelago (Hays, 2008).

Another important factor to consider when looking at the climate of Indonesia is the impact of the Indian Ocean Dipole (IOD) and El Niño Southern Oscillation (ENSO) events. IOD is a pattern of internal variability with anomalously low sea surface temperatures of Sumatra and high sea surface temperatures in the western Indian Ocean, with accompanying wind and precipitation anomalies (Nur'utami and Hidayat 2015). ENSO is a naturally occurring phenomenon involving fluctuating ocean temperatures in the central and eastern equatorial Pacific, coupled with changes in the atmosphere (Nur'utami and Hidayat 2015). Each of these events can be summarized as the result of interactions between the oceans and atmosphere in each respective area. These phenomena are identified by sea surface temperature anomalies and have worldwide impacts on rainfall.

During El Niño, sea surface temperatures are warmer in the Indonesian seas than in the Pacific Ocean. This causes an anomaly of horizontal winds that move toward the Pacific Ocean carrying with it potential vapor for precipitation. La Niña is essentially the opposite, waters are warmer in the Pacific Ocean than the Indonesian seas. Horizontal winds now move from the Pacific to the Indonesian region. IOD events can be thought of in the same manor, although instead of interactions between the Pacific Ocean and Indonesian waters, these processes take place between the Indian Ocean and Indonesian waters. Based on this, a positive IOD can be thought of as El Niño of the Indian Ocean, while a negative IOD would be La Niña equivalent. El Niño can decrease the rainfall by up to 100 millimeters per month while having the most significant loss of rain in eastern Indonesia. Alternatively, La Niña conditions can increase rainfall by up to 100 millimeters per month with eastern Indonesia once again feeling the greatest impact. IOD however, can have various impacts across the region. A positive IOD generally decreases rainfall in the regions of Sumatera and Borneo and increases rainfall in Java, Sulawesi, and Irian Jaya by up to 150 millimeters per month. Negative IOD is shown to increase rainfall by up to 100 millimeters per month in the eastern and western regions of Indonesia, but decrease rainfall by up to 50 millimeters per month in central Indonesia. In the event of a positive IOD and El Niño occurring together, rainfall is more significantly decreased than in the singular event of positive IOD or El Niño. Alternatively, negative IOD and La Niña occurring together have shown a more significant increase than either event occurring independently (Figure 2). Positive IOD – La Niña and negative IOD – El Niño have not been shown to occur (Nur'utami and Hidayat 2015).

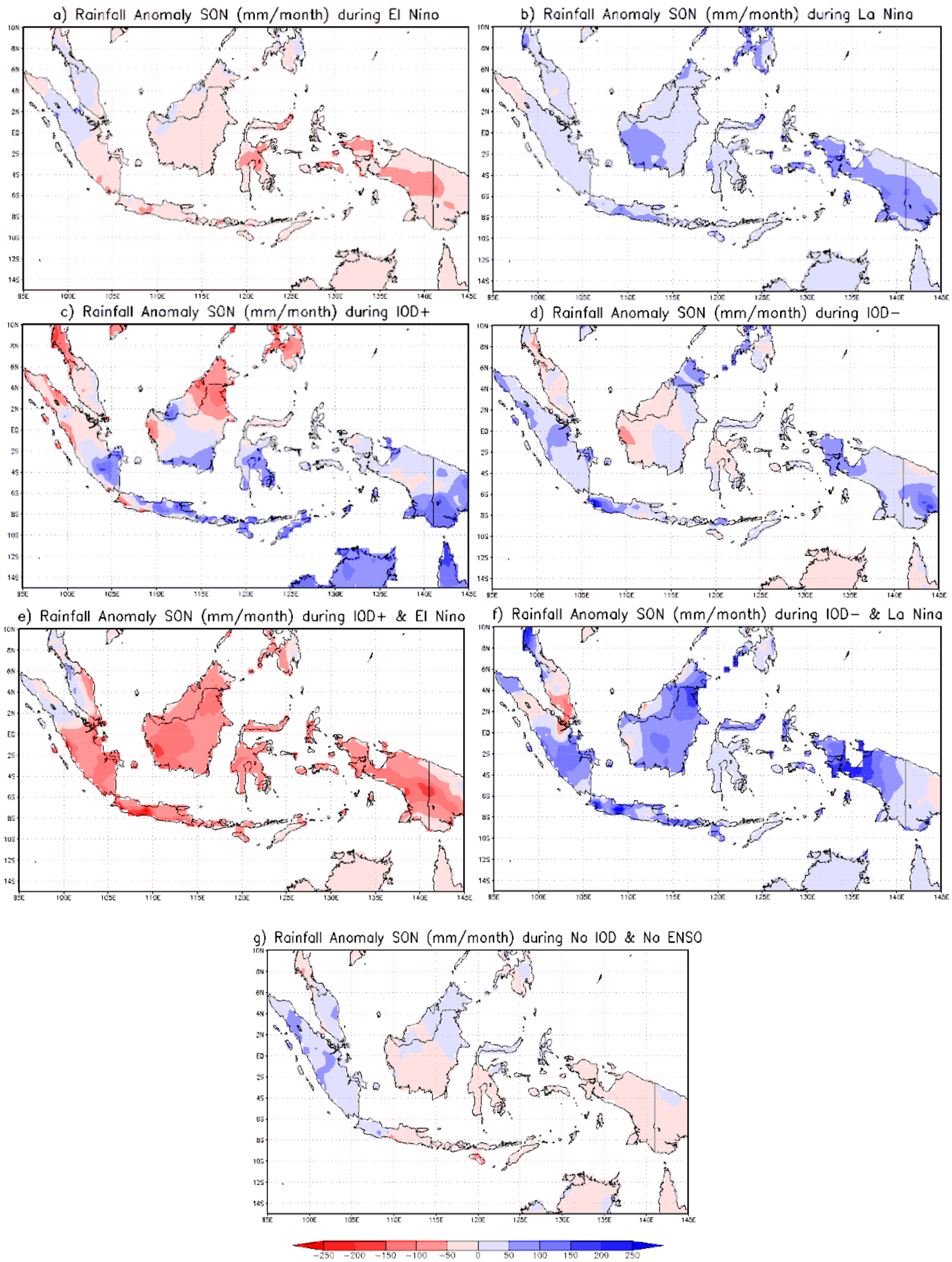

Figure 2: Shows rainfall anomalies (mm/month) of (a) El Niño, (b) La Niña, (c) Positive IOD, (d) Negative IOD, (e) Positive IOD and El Nino, (f) Negative IOD and La Nina, and (g) No IOD and No ENSO (Nur'utami and Hidayat 2015).

Hydrology

The Citarum River originates from the foot of Mount Wayang about 40 km south of Bandung and flows north for approximately 270 km before discharging into the Java Sea. The watershed expands over several ecosystems of river, agricultural land, forest, urban, and rural areas. Following the flow of the river north, there are three reservoirs, the Saguling, Cirata, and Jatiluhur. These are primarily used for hydroelectric power and irrigation, but also serve other purposes.

Seasonality plays a large role in the river discharge, and is even further affected by the ENSO and IOD events mentioned earlier. Base flow of the river hovers around 150 m^3/s. Discharge increases greatly during the wet season with a discharge of approximately 280 m^3/s while decreasing in the dry season to about 50 m^3/s (Sembiring, 2005). ENSO and IOD events can affect this even more by increasing/decreasing precipitation.

As ground subsidence increases, flooding becomes more common and with more intense flooding events. Subsidence rates have been measured at up to 12 cm/yr (Khakim et al., 2014). Groundwater overpumping is generally the main cause of subsidence. Too much pumping can cause clay units within the aquifer fill to collapse. As water is taken from the ground, increasing overburden pressures collapse the pore space between grains. The pore pressures in the clay units essentially supports the column of earth above it. As this pressure declines with pumping, the grains are able to re-arrange and collapse under the weight above it, lowering the elevation of the ground. This becomes a problem during floods as excess water accumulates in the subsided areas. The low lying areas have no way for water to flow out, as they are surrounded by higher ground on all sides, so when a flood occurs the water has nowhere to go and will simply stay on the surface until it evaporates or is slowly pumped over seawalls. This can lead to larger water accumulation and longer flood periods. It is important to note that in several areas the subsidence patterns do not correlate with the distribution of groundwater production wells and mapped aquifer degradation. It was concluded that groundwater production controls subsidence, but lithology is a key factor controlling subsidence in and around Jakarta (Khakim et al., 2014).

Geology

The greater Bandung area of West Java is a large intramontane basin surrounded by volcanic highlands (Figure 3). Geomorphological and sedimentological studies have shown that the

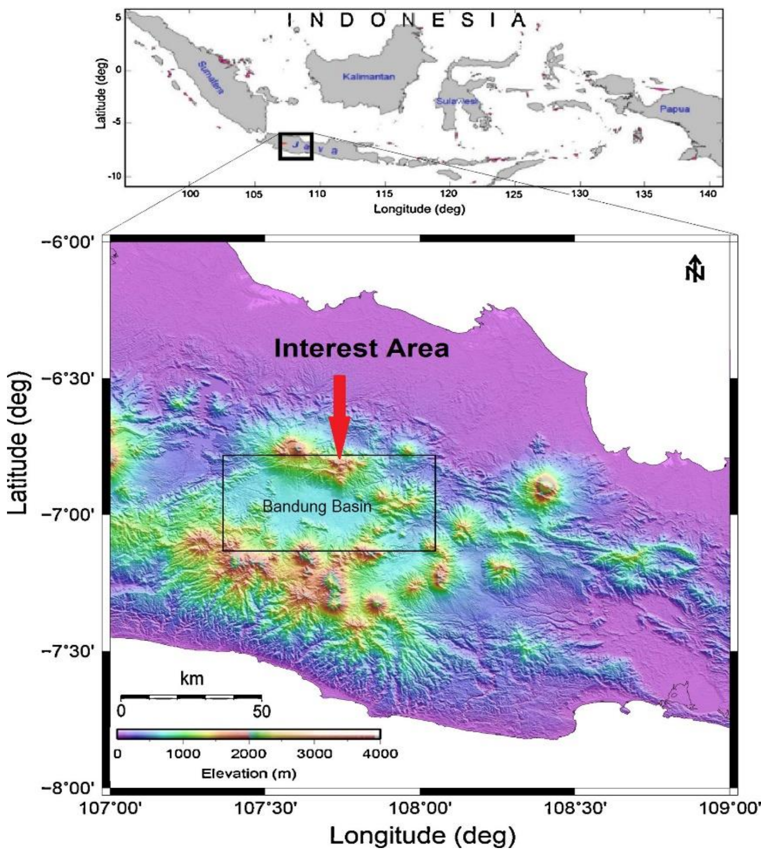

Figure 3: A DEM (digital elevation map) showing the high altitude volcanoes surrounding the lower elevation basin as well as general topography of the area (Khakim et al., 2014).

morphology of the basin developed during the middle – late Quaternary. In particular, tectonic subsidence, paroxysmal eruptions, volcanism-induced faulting/rifting, drainage system adaptations and intramontane lacustrine sedimentation (partly geomorphology-controlled) constitute the dominant landform-determining processes (Dam et al., 1996). The central Bandung plain is approximately 665 meters above sea level and is surrounded by a Late Tertiary and Quaternary volcanic terrain rising up some up to 2400 m.

Regionally, Jakarta is a lowland plain located to the north of the volcanic and alluvial landforms just described. Landforms of marine origin occur immediately adjacent to the coastline. For example, beach ridges stretch east-west along the coast. Swamp and mangrove areas fringe the coastline, as well as paleo-channels running perpendicular to the coast line (Delinom et al., 2008).

Near-surface units in the study area consist of Quaternary and Pliocene sediments, which uncomfortably overlie low permeability Miocene limestone. These limestones crop out in areas to the south as the Bojongmanik and Klapanunggal Formations. The overlying basin fill, which consists of marine Pliocene and Quaternary sand and delta sediments, is up to 300 m thick. Individual sand horizons are typically 1–5 m thick and compose only 20% of the total fill deposits. Silt and clay units separate these horizons. Fine sands and silts are very frequent components of the upper aquifers and the sand layers are connected to each other (Delinom et al., 2008).

Water Resources of Jakarta

Jakarta is not only the capital of Indonesia but also its most populous city with a population of approximately 25 million people. 10 million of those people live within the city itself with the remainder living in surrounding areas. In the last decade alone, the annual domestic demand for water in Jakarta has increased from 243 million m^3 to about 294 million m^3 (Sagala and Pingping, 2015).

Three nearby reservoirs on the Citarum River, the Saguling, Cirata, and Jatiluhur (moving downstream) store water for various uses. Originally created for hydroelectric power and irrigation, they are now being used as storage reservoirs for industrial and domestic water, as well as for fisheries and transportation. As will become clear, there are water quality issues associated with these reservoirs. Generally, the water quality gradually improves downstream, moving from reservoir to reservoir. The Jatiluhur being the farthest downstream is located only 130 km seems far from Jakarta city and is used as another water supply for the city. However, as contaminants continue to be transported from upstream and from other sources, it is only a matter of time until the quality of water deteriorates to that of the upstream reservoirs.

In Jakarta, groundwater also composes a significant source of domestic water. Unfortunately, shallow groundwater from the unconfined aquifer, which is easiest to access, tends to be contaminated. Better quality groundwater is found in deeper aquifers, but this is more expensive to develop and is being depleted by large industrial and domestic withdrawals. At present, groundwater utilization is largely unregulated. So as populations continue to increase, issues of quality, and water availability for both groundwater and surface water is a concern.

Figure 4 provides a sense of how groundwater withdrawals have increased through time. Note, however, that these official government estimates substantially underestimate actual usage because a large proportion of wells drilled are unlicensed. In addition to over-pumping, areas of Jakarta close to the ocean are experiencing problems of saltwater intrusion and land subsidence.

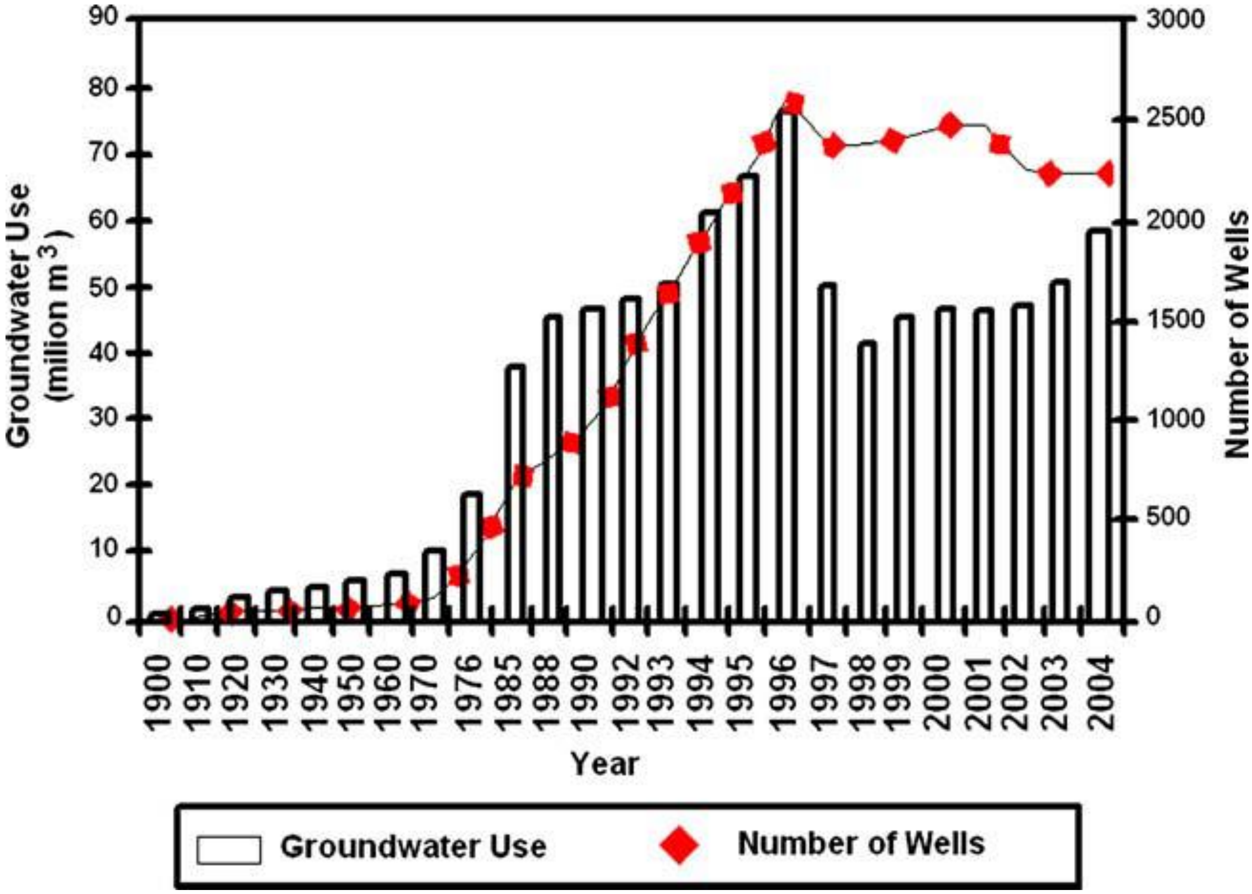

Figure 4: Dramatic increase in groundwater usage and wells drilled before evening out in the early 2000's (Delinom, 2009).

Other sources of water for use in Jakarta include smaller rivers that run directly through the city. These rivers are not nearly as large as the Citarum River but similarly quite polluted.

Contamination of surface waters more generally can be attributed to poor water-management practices and unregulated uses of agrochemicals. Untreated sewage from villages, cities, and agricultural operations are discharged directly to surface waters without treatment. To a large extent, wastes from industrial sources are also discharged directly to surface water. Not too much is known about agricultural contamination and the extent to which fertilizers and pesticides end up in surface water.

The infrastructure of Jakarta has not been updated for many years and was not meant to accommodate the number of people that currently reside there. New people arriving in the city often find themselves living in slum housing without access to city water services or electricity. This is a troubling issue because as the population continues to grow, the quantity and quality of water continues to decline. If action is not taken, it is likely only a matter of time before the city experiences even more critical social and health-related problems.

Contamination of Surface and Ground Water

The Citarum River is notorious for its bad water quality and is often ranked among the most polluted rivers of the world (Cavelle, 2013). The pollution originates from a number of sources. This is not only an environmental concern, but is also a problem for those who live near it and use it for water. The river system is considered to have six broad sources of pollution. These include:

Figure 5: Shows the shear amount of solid waste pollution within the river near Jakarta (Photo credit: Titisari Juwitaningtyas).

1) A large quantity of suspended solids coming from the eroding volcanic highlands surrounding the basin and both fluvial sediments and lacustrine deposits within the basin itself. Turbidity in the river waters is produced by flooding as well as deforestation, which leads to faster runoff and a higher sediment load (van Ginkel, 2015).

2) Industrial effluents from nearby textile factories. Industries that manufacture textiles, paper, and chemicals are responsible for contamination due heavy metals such as zinc, mercury, and selenium, as well as phenol and cyanide (van Ginkel, 2015).
3) Domestic, solid waste is the most readily observable pollutant. Nearly everywhere, there is no program for collecting and disposing of urban solid wastes. This garbage is simply dumped on the river banks to end up floating in the river (Figure 4). Much of the common street litter also ends up there. Factors leading to the problem are citizen behavior and a lack of infrastructure, related to poor city planning, weak governmental institutions and rapid population growth (van Ginkel, 2015).
4) Wastewater and domestic sewage is mostly untreated and discharged into surface water. For example, only 35% of the city of Bandung, mainly the east side, is connected to a centralized wastewater treatment plant, the Bojongsoang. According to Prihandrijanti and Firdayati (2011), the operation of this plant is not effective, reducing its capacity by more than 50%. In most cases, age old sewer systems dump waste directly into the river or commodes are built along the river's edge. Septic tanks are common in rural areas, but are poorly constructed which leads to seepage or direct discharge into the groundwater system. Both the domestic solid waste and the domestic sewage problems are related to inadequacies of various levels of government. Many poor people, with little education and no income live in illegal housing, especially on the river banks. These slums do not have any infrastructure and are thus contributing significantly to the waste and sewage disposal (van Ginkel, 2015).
5) Agricultural wastes are another significant source of contamination. Herbicides and pesticides run off into nearby streams and rivers and are responsible for high levels of

dissolved nitrogen, as well as other pollutants. Farmers are often poorly educated and use their own, intuitive mix of pesticides and herbicides that can be more harmful than environmentally friendly ones (van Ginkel, 2015).

6) Lastly, there is significant loading of animal wastes from animal production operations. Loading of these wastes starts in the first kilometer downstream of the Situ Cisanti, the spring of the Citarum. These operations are in close vicinity to the river and are responsible for dumping of manure into the river. A local non-government organization has estimated that 90% of all manure produced is discharged directly into the river (van Ginkel, 2015).

Any one of these sources has the potential to create a serious problem of contamination in surface waters. When all of these sources are operating at the same time, one can begin to understand why the Citarum River is considered one of the most highly polluted rivers in the world.

a)

Quality Status	Pollutant Index					
	2004	2005	2006	2007	2008	2009
Good	0%	0%	3%	0%	0%	0%
Low Polluted	3%	5%	9%	0%	0%	9%
Moderate Polluted	16%	16%	10%	6%	12%	9%
High Polluted	81%	79%	78%	94%	88%	82%
Total	100%	100%	100%	100%	100%	100%

b)

Quality Status	Pollutant Index					
	2004	2005	2006	2007	2008	2009
Good	18%	16%	7%	25%	23%	23%
Low Polluted	33%	33%	55%	43%	48%	41%
Moderate Polluted	28%	35%	13%	20%	16%	19%
High Polluted	21%	16%	25%	12%	13%	17%
Total	100%	100%	100%	100%	100%	100%

Table 1: The pollution index for surface water (a) and groundwater (b) in Jakarta. There appears to be little improvement with time. (Sagala and PingPing, 2015).

Contamination Standards in Indonesia

In Indonesia, the government has created water quality standards. These are summarized in Table 2 for the following four types of water:

1) Drinking water or any other use with the similar requirements.

2) Service water, recreational, gardening or any other use with the similar requirements.

3) Fresh water agricultural, farming and any other use with the similar requirements.

4) Irrigation and any other use with the similar requirements.

		water class						water class			
Parameter	Unit	1	2	3	4	Parameter	Unit	1	2	3	4
Physical						*Anorganic (continued)*					
Temperature	C	± 3	± 3	± 3	± 5	Cyanide	mg/l	0.02	0.02	0.02	
TDS	mg/l	1000	1000	1000	2000	Fluoride	mg/l	0.5	1.5	1.5	
TSS	mg/l	50	50	400	400	Nitrite as N	mg/l	0.06	0.06	0.06	
Anorganic						Sulphate	mg/l	400			
pH		6-9	6-9	6-9	5-9	Free Chlorine	mg/l	0.03	0.03	0.03	
BOD	mg/l	2	3	6	12	Sulfur as H2S	mg/l	0.002	0.002	0.002	
COD	mg/l	10	25	50	100	Microbiology					
DO	mg/l	6	4	3	0	Fecal coliform	Jml/100 ml	100	1000	2000	2000
Total Fosfat sbg P	mg/l	0.2	0.2	1	5	Total coliform	Jml/100 ml	1000	5000	10000	10000
NO 3 as N	mg/l	10	10	20	20	*Radioactive*					
NH3-N	mg/l	0.5				- Gross-A	Bq/l	0.1	0.1	0.1	0.1
Arsen	mg/l	0.05	1	1	1	- Gross-B	Bq/l	1	1	1	1
Kobalt	mg/l	0.2	0.2	0.2	0.2	*Organic chemical*					
Barium	mg/l	1				Minyak dan Lemak	µg/l	1000	1000	1000	
Boron	mg/l	1	1	1	1	Detergen[22]	µg/l	200	200	200	
Selenium	mg/l	0.01	0.05	0.05	0.05	Fenol[23]	µg/l	1	1	1	
Kadmium	mg/l	0.01	0.01	0.01	0.01	BHC	µg/l	210	210	210	
Chrome (VI)	mg/l	0.05	0.05	0.05	1	Aldrin / Dieldrin	µg/l	17			
Copper	mg/l	0.02	0.02	0.02	0.2	Chlordane	µg/l	3			
Iron	mg/l	0.3				DDT	µg/l	2	2	2	2
Lead	mg/l	0.03	0.03	0.03	1	Heptachlor (epoxide)[24]	µg/l	18			
Manganese	mg/l	0.1				Lindane	µg/l	56			
Mercury	mg/l	0.001	0.002	0.002	0.005	Methoxyclor	µg/l	35			
Zinc	mg/l	0.05	0.05	0.05	2	Endrin	µg/l	1	4	4	
Chloride	mg/l	600				Toxaphan	µg/l	5			

Table 2: Water quality standards per water use type according to national government decree (van Ginkel, 2015).

It is not clear with which class the water quality of the Citarum should comply. After consideration with the West Java EPA, it was decided to use the norms of class 3 (van Ginkel, 2015).

Concentration of Major Pollutants

The Citarum suffers multiple forms of pollution ranging from physiochemical to microbial. Temperature, pH, conductivity, turbidity, dissolved oxygen (DO), salinity, total dissolved solids (TDS) and oxidation reduction potential (ORP) were determined at each sampling site by Multi-Probe W23XD system, free and total chlorine, iron (Fe(II)) and ammonia nitrogen (NH_3-N) were measured using a DR/890 Colorimeter. Total coliforms and E. coli were determined on the same day of sampling by a membrane filtration technique using m-ColiBlue24 Broth (Phanuwan et al., 2006). The concentrations of enteric viruses, total coliforms and E. coli are summarized in Table 3.

Parameters	Unit*	Geometric mean concentration (range)		Min and max concentration groundwater	
		Floodwater ($n = 2$)	Ciliwung River ($n = 7$)	Flooded area ($n = 3$)	Non-flooded area ($n = 5$)
Viruses					
Enterovirus	PDU/mL	30 (12–72)	0.7 (0.2–2.2)	ND–0.022	ND**
Hepatitis A virus	PDU/mL	79 (71–87)	13.0 (4.0–33)	ND–1.0	ND
Norovirus G1	PDU/mL	0.19 (0.18–0.19)	0.03 (0.01–0.04)	ND–0.013	ND
Norovirus G2	PDU/mL	26 (22–30)	5.3 (1.0–16)	ND–8.9	ND
Adenovirus	PDU/mL	55 (51–60)	14.0 (0.5–120)	ND–0.80	ND
Bacterial indicators					
Total coliforms	10^3 CFU/mL	440 (95–2000)	4.2 (1.1–16)	0.007–4	ND–0.014
E. coli	10^3 CFU/mL	24 (9–65)	0.6 (0.2–1.1)	ND–1.7	ND

*CFU/mL = colonies forming unit/mL, and PDU/mL = PCR detection unit/mL; **ND = not detected

Table 3: Shows concentration of viruses and bacterial indicators in floodwater, river and groundwater (Phanuwan et al., 2006).

All viruses tested were found in floodwater samples. The most abundant virus in floodwater was Hepatitis A (79 PDU/mL), followed by adenovirus (55 PDU/mL), Enterovirus (30 PDU/mL) and Norovirus G2 (26 PDU/mL). Norovirus G1 was approximately 100 times less than Norovirus G2. Enterovirus, hepatitis A virus, adenovirus and norovirus G2 were found in all samples taken from Ciliwung River whereas norovirus G1 was found in 4/7 samples. The most abundant virus in river water was adenovirus with a geometric mean of 14.0 PDU/mL, followed by hepatitis A virus (13.0 PDU/mL), norovirus G2 (5.3 PDU/mL), enterovirus (0.7 PDU/mL) and norovirus G1 (0.03 PDU/mL), respectively. The results revealed that enteric viruses, especially hepatitis A virus and adenovirus, were prevalent in Jakarta (Phanuwan et al., 2006).

The concentration of total coliforms and E. coli were in the range 1.1 x 10^3 –1.6 x 10^4 and 2.0 x 10^2 –1.1 x 10^3 CFU/mL, respectively. The floodwater samples showed much higher concentrations than river waters for all bacterial indicators and viruses save adenovirus. The greater microbial contamination level in floodwater than in the Ciliwung River indicated a higher health risk during flood events than the normal seasons (Phanuwan et al., 2006). In Ohio, for example, total coliforms for private wells should be < 4 CFU/mL (Frasson, 2018), Jakarta floodwaters show approximately 100,000X that in 2006.

Physicochemical parameters in floodwater, river and groundwater are shown in Table 4.

Parameter*	Unit	Mean (range)			
		Floodwater (*n* = 2)	River (*n* = 7)	Groundwater	
				Flooded area (*n* = 3)	Non-flooded area (*n* = 5)
pH	–	7.2 (6.8–7.6)	7.4 (6.8–8.0)	6.9 (6.9–7.0)	6.7 (6.6–6.9)
Conductivity	mS/m	16 (14–17)	19 (10–29)	87 (31–120)	82 (59–110)
Turbidity	NTU	670 (410–920)	230 (40–660)	9 (0–26)	3.2 (0–13)
DO	mg/L	7.9 (7.8–8.0)	8.4 (7.8–8.8)	5.3 (5.0–5.5)	5.7 (4–6.4)
Temperature	°C	26.3 (26.1–26.4)	24.7 (23.3–25.6)	28.1 (27.5–28.7)	29.1 (28.0–29.8)
TDS	g/L	0.10 (0.09–0.11)	0.10 (0.07–0.16)	0.6 (0.2–0.8)	0.5 (0.4–0.7)
ORP	mV	110 (80–140)	250 (200–320)	250 (190–280)	320 (260–420)
Chloride	mg/L	22 (17–27)	17 (8–31)	63 (28–82)	81 (52–115)
Fe(II)	mg/L	18 (17–19)	0.09 (0.03–0.24)	0.04 (0.01–0.07)	0.06 (0.00–0.18)
NH_3-N	mg/L	2 (0–2)	0.14 (0.0–1.0)	4.7 (0–14)	8.6 (0–28)

*ADO: dissolved oxygen, TDS: total dissolved solids, ORP: oxidation reduction potential, Fe(II): ferrous iron, and NH_3-N: ammonia nitrogen

Table 4: Physicochemical parameters in floodwater, Ciliwung River and ground water (Phanuwan et al., 2006).

The results showed a statistically significant correlation between the physicochemical parameters (including conductivity, turbidity, temperature, TDS and ORP) with all viruses and bacterial indicators tested. Turbidity showed positive correlation with all the microbes tested while conductivity, temperature, TDS and ORP showed negative correlation (Phanuwan et al., 2006).

Discussion

Issues

The city of Jakarta is plagued with a multitude of problems, from pollution and flooding to poverty and corruption. Where does one begin in fixing these problems before they spiral out of control? Indonesia is a relatively poor country to begin with, and to tackle issues of this magnitude would take time and most importantly, money. According to the Asian Development Bank (ADB) 5.9% of the urban population of Indonesia is multidimensionally poor, while an additional 8.1% are near multidimensionally poor (ADB, 2016). Poverty is even greater when the rural population is taken into account, as an estimated 16.6% live in poverty. However, the most highly concentrated areas of poverty lie on the island of Java with West Java, Central Java, and East Java each having more than 5 million poor people on average during 2006–2011 (ADB, 2016). With this many people living in poverty, it is difficult for the Indonesian government to focus on environmental monitoring and restoration. Their main focus lies in keeping the economy afloat so that the entire country doesn't plunge into complete pandemonium.

What little water quality monitoring and management data they do have is unclear even after two decades of so-called "reforms" in the Indonesian water sector. A decentralization policy is in place that transfers power from the central government to the autonomous regional governments. This process is to overall improve the regulation and administration of water-related affairs of the government in Indonesia. According to the decentralization policy, river management should be organized on the lowest administrative level that completely encloses a water body. For example: if a small tributary is fully located within a certain regency, the district level government is responsible for managing the water quality in this tributary. However, when a river passes through multiple districts, it is under responsibility of the provincial government (van Ginkel et al., 2015). Basically, if a small tributary is fully enclosed within a district, the district level government is responsible for monitoring and maintaining the water quality, but if a river passes through multiple districts it is the job of the provincial government.

Based on the decentralization policy, one would expect that river management of the Citarum is the responsibility of the West Java government, and indeed, there is a Provincial Water Resources Agency: the BPSDA. However, the Indonesian government decided that the Citarum River Basin is of great strategic importance for the country, because it supplies water to Jakarta, which is outside the West Java province, and that it therefore should be managed on national level. Thus, a river basin organization under direct responsibility of the ministry of Public Works was established by law in 2004, the BBWSC.

The position of the old river basin organization, the BPSDA, was weakened because they had to hand over responsibilities to the BBWSC but also to the district level governments as part of the decentralization policy (van Ginkel et al., 2015). The West Java EPA is still considered as the most important stakeholder with regard to water quality monitoring in the basin. However, decentralization handed over the main monitoring responsibilities of the West Java EPA to the district EPAs. Meanwhile, the official authority to monitor the Citarum River was transferred to the national government. As a result, most of the monitoring activities are carried out by other stakeholders in the basin. The West Java EPA still has the responsibility to formulate and execute the water quality policy in the basin, but lacks resources and authority to carry out this task (van Ginkel et al., 2015). This has led to multiple organizations doing individual water quality assessments with little interaction and collaboration among them, leaving a strong need for coordination of monitoring activities and data.

Overall, the water quality situation of the Citarum does not have a good prognosis. Monitoring is being done, but it is limited. Communication between the monitoring agencies is virtually non-existent, leading to a stagnation of progress. Given all the circumstances and problems associated with the river and Jakarta as a whole, this situation has been allowed to snowball out of control and will be difficult to reverse. Lack of communication makes it difficult to implement preventative measures and mitigation strategies. The expansive list of problems cannot be fixed all at once, and will take money, cooperation, education, and most importantly, time.

Impacts on Humans and the Environment

Pollution to this extent can have major repercussions on the environment and the population that relies on the Citarum River as a water resource. Water-related health hazards are mostly due to harmful organisms or chemicals consumed when drinking water and to diseases which have part of their life cycle in water or with water-related vectors (e.g., malaria). Of the sources of contamination discussed earlier, a few are of particular concern. In particular, domestic sewage and fecal matter contamination leads to a variety of diarrheal diseases, many of which are directly related to bacteria in the water. According to the ADB (2016) the most important causes of under-5 mortality in Indonesia are diarrhea and typhoid. These diseases are usually caused by fecal-borne contamination of water, directly linked to inadequate supplies of high quality water, sanitation, and hygiene issues. The total number of deaths attributed to poor sanitation and hygiene exceeds 50,000, of which 24,000 are accounted for by direct diseases, mainly diarrhea. The combination of untreated domestic sewage, solid waste disposal, and industrial effluents has led to a major public health crisis. (ADB, 2016).

Triggered by the fierce economic growth of the past decades and the continuing population growth and urbanization, the pressures on the water-supply systems in Indonesia are increasing, especially in the highly urbanized areas. Increased water consumption and a decrease in the availability of clean water affect both the freshwater systems and the groundwater systems. Deforestation, drainage of wetlands, and conversion into agricultural land-use all over the country reduce the buffering capacity of the river catchments, resulting in higher peak flows in the wet season and lower base flows in the dry season, thereby increasing the risks of floods and droughts. Increased concentrations of suspended solids resulting from erosion and human activities leads to higher levels of turbidity, and thus reduces photosynthesis. Dams and reservoirs play a major role in fragmenting and modifying aquatic habitats, transforming flowing ecosystems into stagnant systems, altering the flow of matter and energy, and establishing barriers to fish migration. Eutrophication, as a result of agricultural practices, is a major cause of deterioration in water quality and might, in some cases, result in harmful algae blooms and fish mortality (ADB, 2016).

Conclusions and Suggestions for Future Research

The situation in Java is extremely unfortunate. The millions of people affected by the impaired water quality is hard to put into perspective. One can only imagine the living conditions and hardships faced by a population without access to reliable clean water, a basic requirement for human survival. Without government intervention, the degradation in water quality shows no signs of slowing down. No one person is able to fix this problem. It has become so complex and has so many influencing factors that government intervention is necessary in order to reverse the process. Yet, perhaps the problem has reached the point of no return. Surface water contamination has led to excessive groundwater pumping, which in turn leads to ground subsidence and seawater intrusion. There are little to no enforced regulations on dumping, and cleanup efforts are virtually nonexistent.

Future research and investigation is needed to better understand the full extent of problems of water quality. With organizations doing limited sampling and having little communication, it is impossible to know the true extent of the water problem. Assessment and monitoring of point-source pollution discharges should also be required. With little to no regulations on dumping, it is essentially a free for all. Corruption is rampant throughout Indonesia, so who knows what may be dumped into the water while the government turns a blind eye. It is not too late for the people of Java. With preventative measures, accurate water quality data, and government intervention, these problems are fixable.

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